



Exploration Systems Mission Directorate

Exploration Transportation Strategic Roadmap

Stage-Setting Discussion



*Mark S. Borkowski
Mission Directorate Roadmap Coordinator
February 3, 2005*



Agency Goal Statement

Exploration Transportation Systems **Strategic Roadmap #5**

“Develop an exploration transportation system to deliver crew and cargo from the surface of the Earth to exploration destinations and to return the crew safely to Earth”



Earlier Draft--Agency Goal Statement

Exploration Transportation Systems Strategic Roadmap #5

“Develop a new crew exploration vehicle to provide crew transportation for missions beyond low Earth orbit. First test flight to be by the end of this decade with operational capability for human exploration no later than 2014.”



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Exploration Transportation Systems Strategic Roadmap #5

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Exploration Transportation is More than Just the Crew Exploration Vehicle—but It’s Still a Large Piece



CEV Objectives

- **To support the objectives of Project Constellation, NASA will develop a Crew Exploration Vehicle that will provide safe, affordable, transportation for humans from the Earth to the Moon, Mars and beyond and return them safely to Earth. To this end, NASA will:**
 - **Pursue a Crew Exploration Vehicle design that allows for human transportation from the surface of the Earth to orbit around the Moon or Mars and return from that orbit to the Earth's surface**
 - **Ensure that the Crew Exploration Vehicle is designed from the outset as a key element of the Constellation “system of systems.”**
 - **Ensure that the capabilities of the Crew Exploration Vehicle can be expanded in a sustainable, affordable manner as new technology becomes available and new missions are defined.**



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Constellation System of Systems



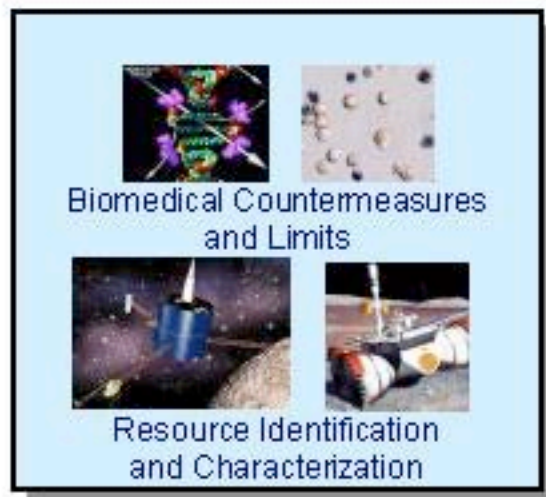
Transit and Launch Systems



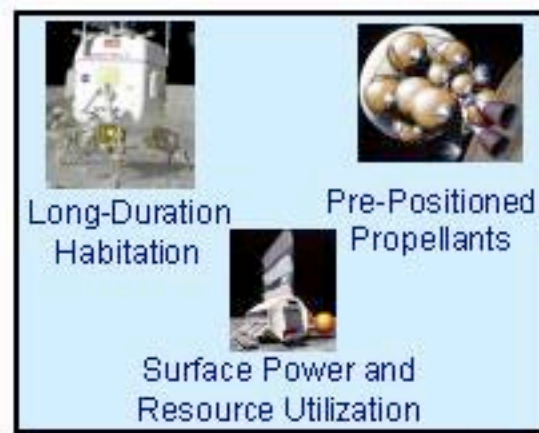
The Human -
an Essential
Element of the
System of
Systems



Surface and Orbital Systems



Supporting Research



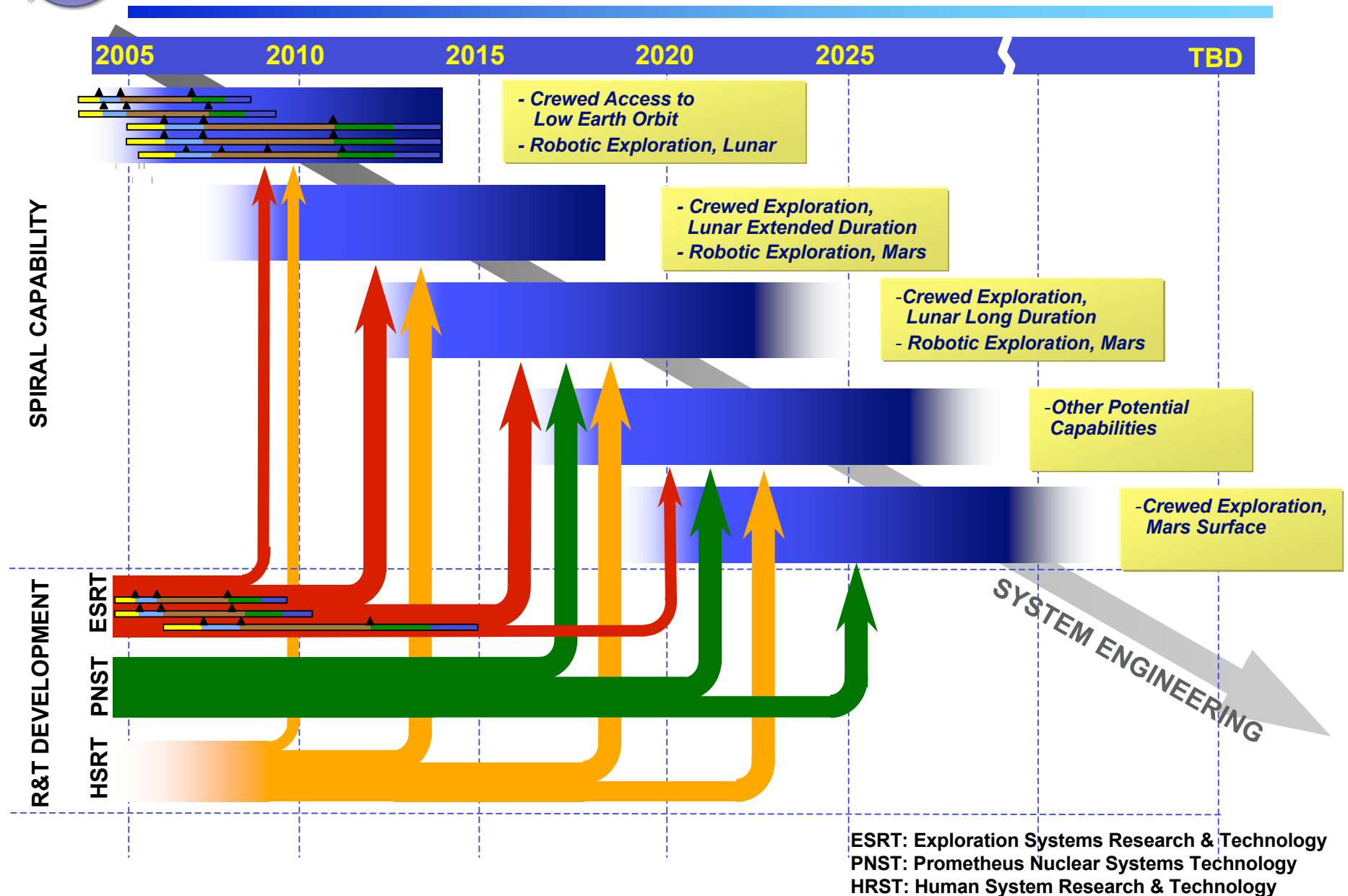
Technology Options



Commonality/Evolvability For Future Missions

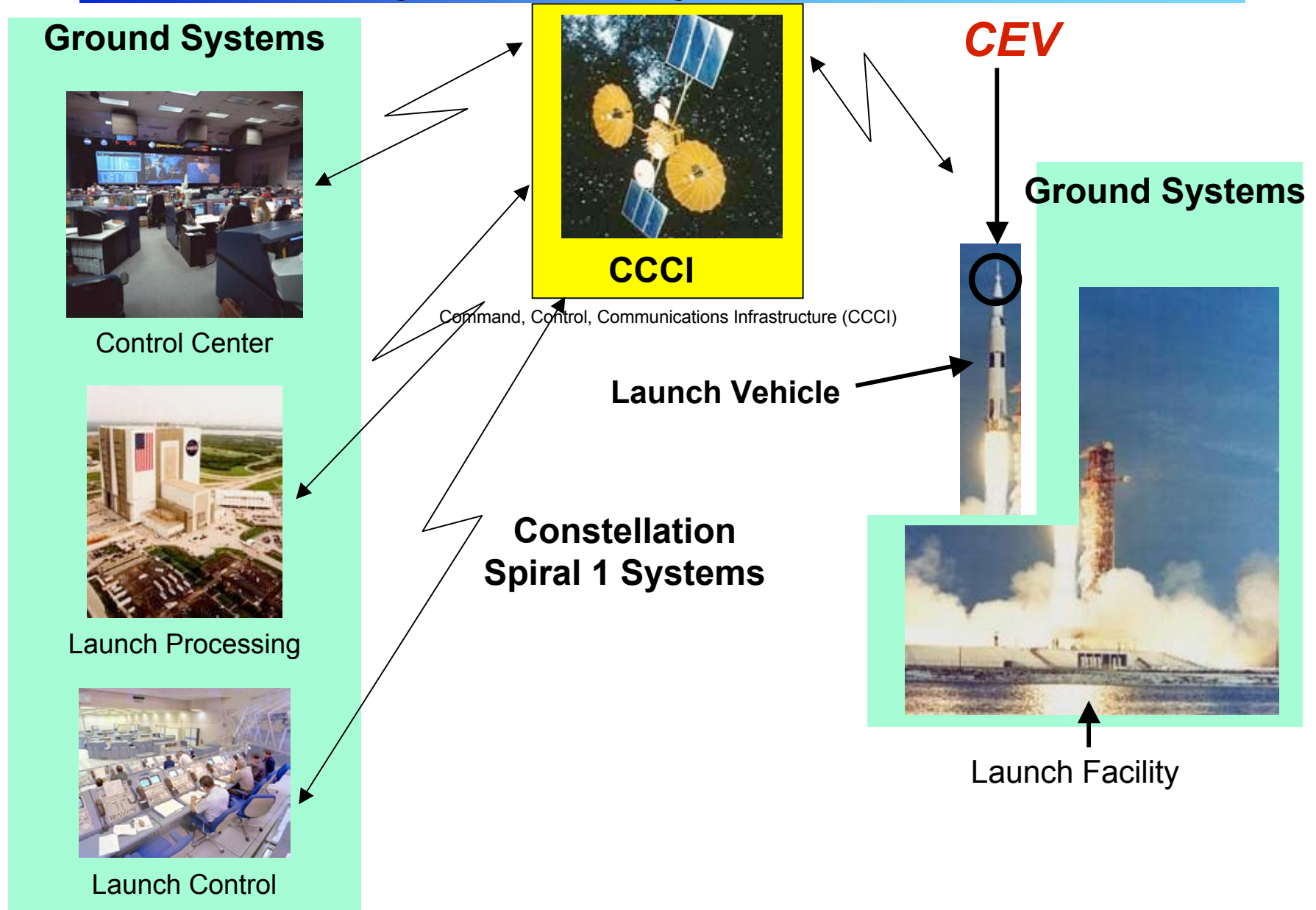


Project Constellation Acquisition Spirals



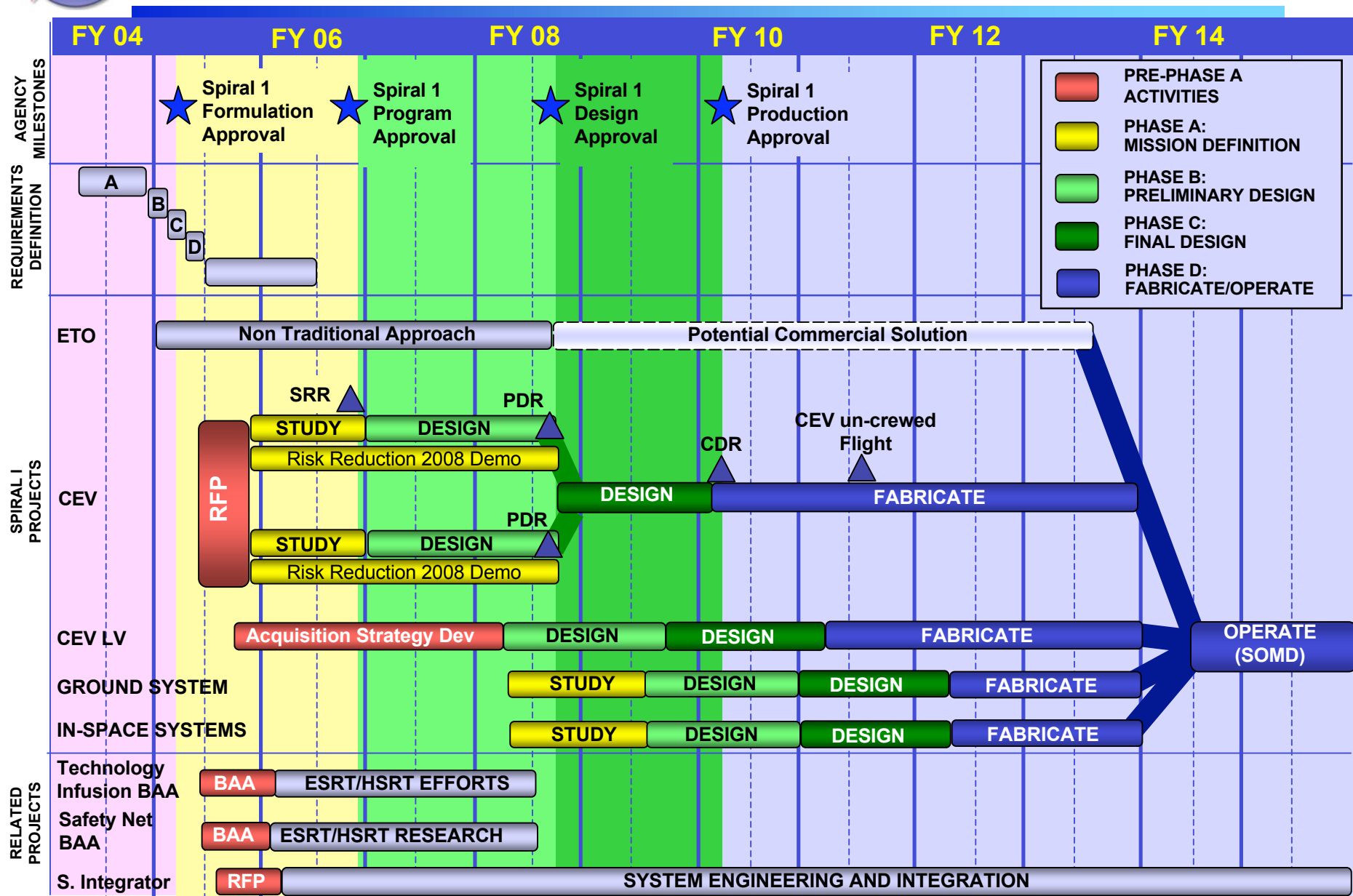


CEV—An Element of Constellation System of Systems





Spiral I Program



ETO: Earth-to-Orbit CEV: Crew Exploration Vehicle LV: Launch Vehicle BAA: Broad Area Announcement SOMD: Space Ops Mission Directorate



Strategic Roadmap—Our First Challenge

- Exactly what are the elements of Exploration Transportation?
- Which of them require the attention of this committee?
- We can be advised by
 - The design of the Constellation System of Systems
 - The development of other, related roadmaps...



Capability Roadmaps Relevant to SRC-5

**In-Space
Transportation**

Transportation

**Autonomous
Systems & Robotics**

**In-Situ Resource
Utilization**

ConOps Enablers

**Transformational
Spaceport & Range**

Infrastructure

**High Energy
Power & Propulsion**

**Nanotechnology &
Advanced Concepts**

Technology

**Human Health and
Support Systems**

**Human Planetary
Landing Systems**

**Human Exploration
Systems & Mobility**

Human System Enablers



Roadmap for Evolutionary ISRU Campaign

Capabilities

Initial

Mid-Term

Long-Term

Resource Assessment

- Remote & Local Sensors
- Simulants

In-Situ Resource Excavation & Separation

- Regolith Excavation
- Thermal/Microwave Extraction
- H₂O Separation
- CO₂ & N₂ Separation

Resource Processing

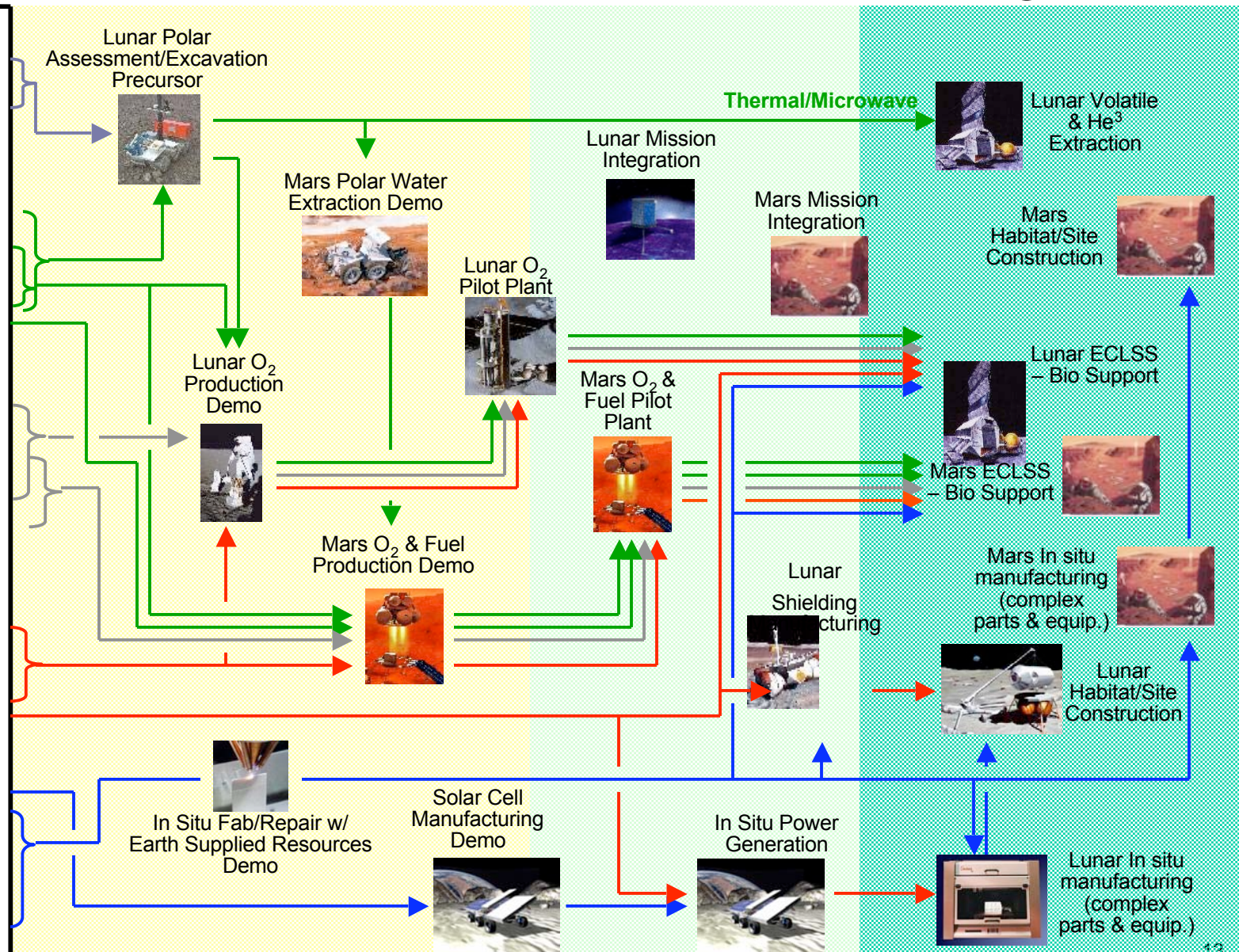
- Regolith Reduction for O₂ & Feedstock
- CO₂ Reduction
- H₂O Reduction
- Fuel Production

Consumable Storage & Distribution

- Cryocoolers
- Light Weight Tanks
- Disconnects/pumps
- Transfer/Distribution

In-Situ Manufacturing

- Solar cell production
- Metallic part fab
- Polymer part fab.
- Ceramic part fab.
- Manufacturing NDE
- Metrology Processes





Strategic Roadmaps Relevant to SRC-5

**Lunar
Expeditions**

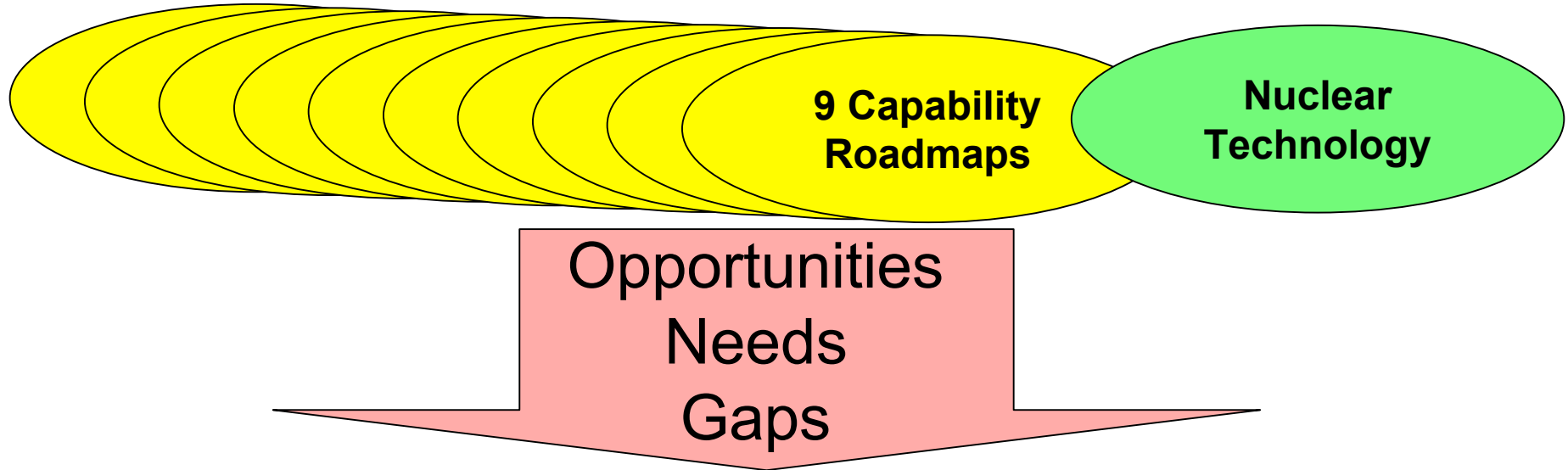
**Mars
Exploration**

**Shuttle
Transition (deferred)**

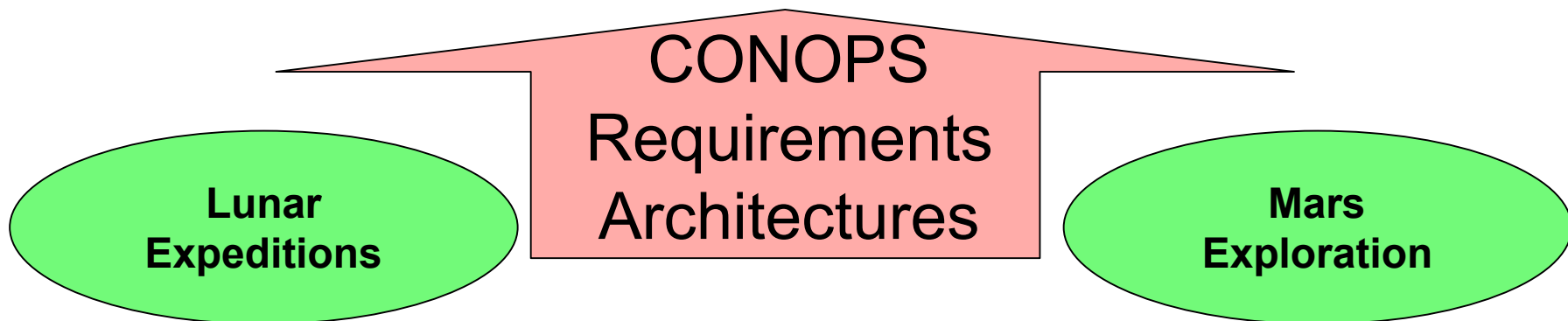
**Nuclear
Technology**



Roadmap Relationships...

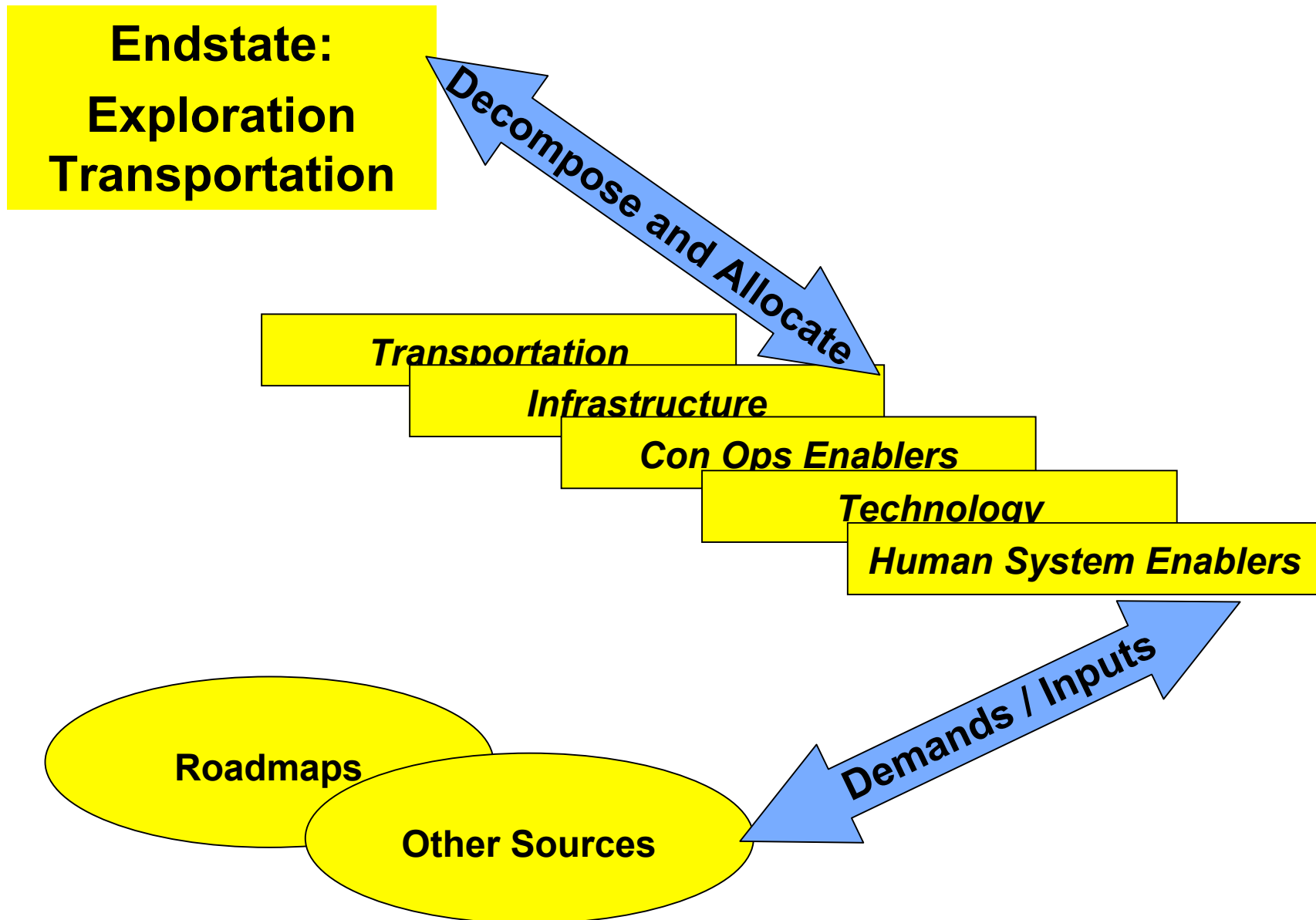


SRC-5: Exploration Transportation Roadmap





Potential Analysis Flow...





Potential Analysis Flow...

Consider each spiral...

**Endstate:
Exploration
Transportation**

Decompose and Allocate

Transportation

Infrastructure

Con Ops Enablers

Technology

Human System Enablers

**Are we missing something?
How do we get it?
When do we need it?**

Roadmaps

Other Sources

Demands / Inputs



Exploration Transportation System Strategic Roadmap Philosophy

- Broad science and exploration goals
- High level milestones, options, and decision points
- **Show the alternative paths and decision points, rather than choosing a path**
- Key dependencies and relationships to other Strategic Roadmaps
 - **Transportation is cross cutting**
 - It ties to almost all of the other Strategic Roadmaps, especially the ISS, Lunar, and Mars Roadmaps



By the way...

- **Latest revision of Space Transportation Policy will impact us...**
 - **Provides direction on who conducts Space Transportation—and how**
 - **Directs development of a series of strategic plans**
- **Our Strategic Roadmap will be constrained by, and responsive to, the National policy...**



New National Space Transportation Policy

- **President authorized new national policy on December 21, 2004, that establishes national policy, guidelines, and implementation actions for US space transportation programs and activities to ensure Nation's ability to maintain access to and use space for U.S. national and homeland security, and civil, scientific, and commercial purposes.** } **Goal**
- **Objectives:**
 - Ensure availability of US capabilities for reliable and affordable space access, including access to, transport through, and return from space;
 - Demonstrate initial capability for operationally responsive access to and use of space -- providing capacity to respond to unexpected loss or degradation of selected capabilities, and/or to provide timely availability of tailored or new capabilities -- to support national security requirements;
 - Develop space transportation capabilities to enable human space exploration beyond low Earth orbit;
 - Sustain focused technology development program for next-generation space transportation capabilities that dramatically improves, and enables decision to acquire these capabilities in the future;
 - Encourage and facilitate US commercial space transportation industry to enhance national security and civil space transportation objectives, benefit US economy, and increase industry's international competitiveness; and
 - Sustain and promote domestic space transportation industrial base, including launch systems, infrastructure, and workforce.



This First Meeting—Our Goals

- **Build consensus on the boundaries of the Exploration Transportation Roadmap**
- **Provide an introduction to some potential roadmap inputs**
- **Discuss strategies for developing the details of the roadmap**
- **Begin to identify gaps in knowledge or understanding**
- **Brainstorm to provide inputs for staff analysis and synthesis**
- **Identify requirements, actions, and desired content for our next meeting**



Approach

- **Day One**
 - Background, “ticklers,” and food for thought
 - Introduction to potential roadmap framework
- **Evening, Day One**
 - Break to “sleep on it”
- **Day Two**
 - Open discussion
 - We’ll provide some questions as catalysts
 - We hope to hear your brainstorming...
 - Staff engineers will listen, record—and then go home to synthesize the results
- **Next meeting**
 - Provide additional background as desired
 - Present the synthesized product for discussion and modification



Agenda

Morning, February 3, 2005

- ***8:00 Meeting Opening***

- Call to Order
- Introduction of committee members
- Strategic Roadmapping Process
- Objectives/Charter/Expectations/Vision

Dana Gould
Members
Marc Allen
Co-chairs

- ***9:30 Stage Setting***

Mark Borkowski

- ***10:30 Session 1: Background Briefings***

- Requirements and Point of Departure Architecture
- Constellation Analysis of Alternatives

Scott Chandler
Cris Guidi

- ***11:30 Working Lunch***

- FACA Briefing
- Ethics Briefing

Diane Rausch
Andrew Falcon



Agenda

Afternoon, February 3, 2005

- ***12:30 Session 2: Special Topics***
 - **Space Operations Perspective** Karen Poniatowski
 - **Department of Defense Perspective** Jim Knauf
 - **Technology Development** John Mankins

- ***2:45 Committee Discussion*** Members

- ***3:15 Strawman Roadmap Philosophy and Plan*** Steve Cook

- ***4:30 Session 3: APIO RFI Responses – Input from Industry, Academia, and Others***
 - **Transportation Strategic Systems Roadmap RFI Responses** Ruth Gardner

- ***6:00 Adjourn***



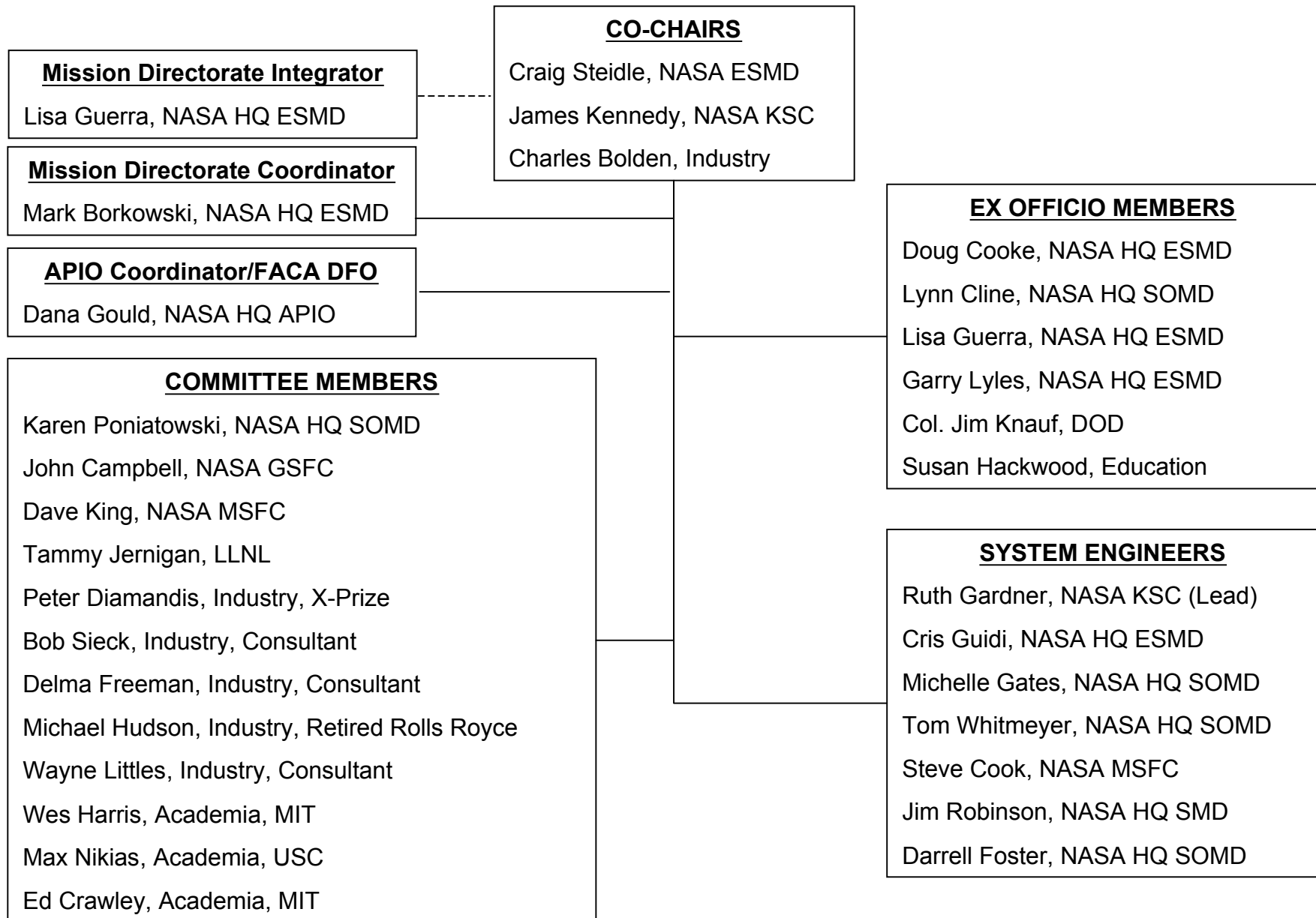
Agenda

February 4, 2005

- ***8:00 Review of Strawman
Roadmap*** **Steve Cook/Team**
- ***11:00 Preparation for
Next Meeting*** **Co-Chairs & Members**
- ***12:00 Adjourn***



Committee Membership





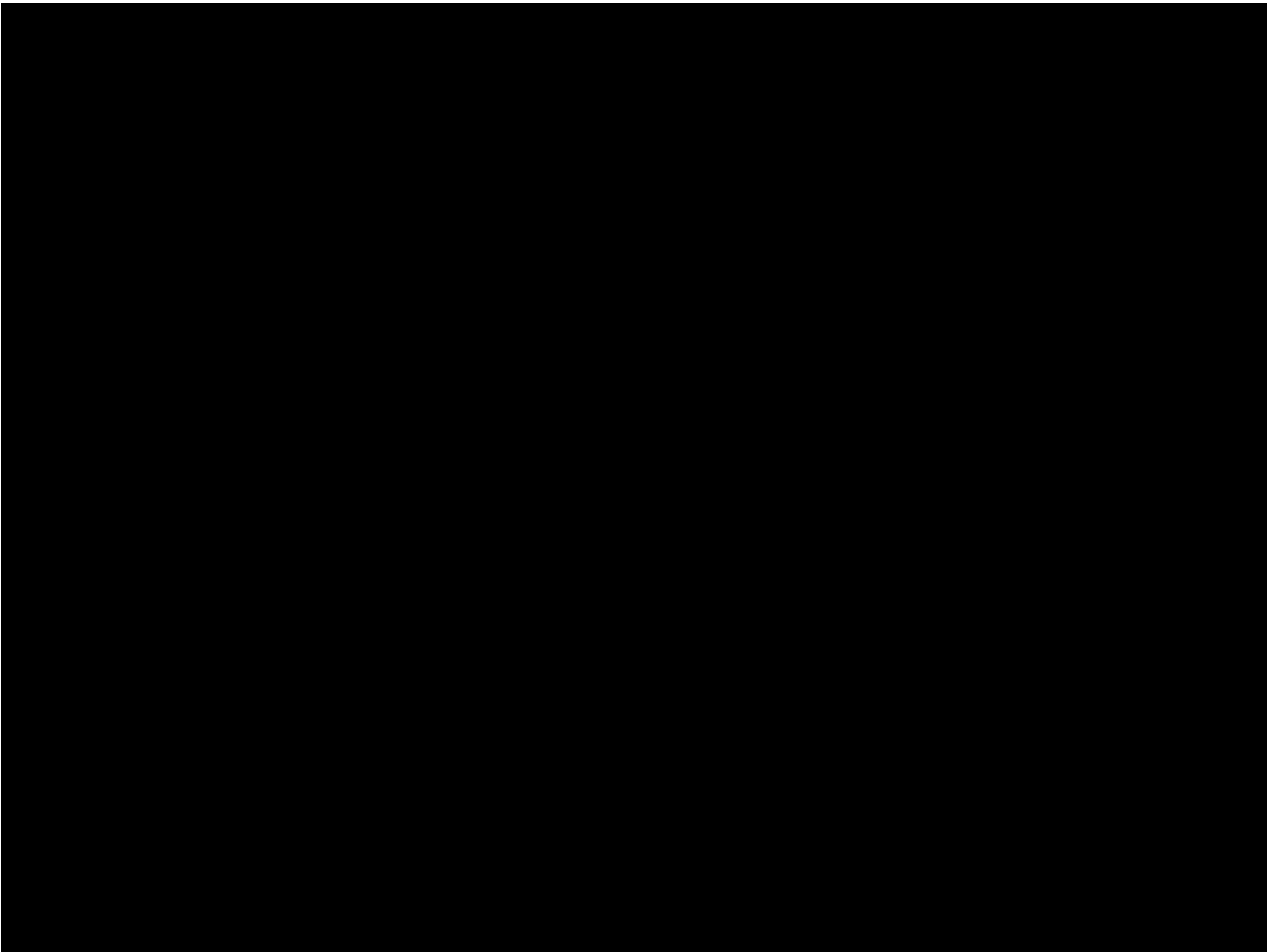
Key Dates

- **First Committee Meeting – February 2005**
- **Second Committee Meeting – April 2005**
- **Submit Draft Roadmaps to NRC for Review – June 2005**
- **Receive NRC Comments – August 2005**
- **Third Committee Meeting – August 2005 – but will depend on NRC schedule**
- **Complete Roadmap – September 2005**



Summary

- **This is a big job—very important to NASA and very complex**
- **Our roadmap has extensive linkages to many of the other NASA roadmaps**
- **“Exploration Transportation” is a very broad term—we need to start to draw boundaries around it**
- **This first meeting is designed to provoke thought and discussion—we hope to leverage your expertise and experience!**



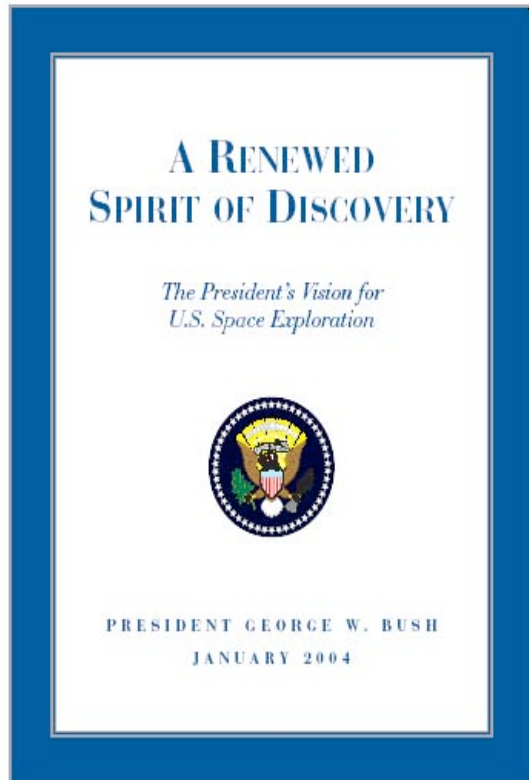


Backups...



The Vision for Space Exploration

**THE FUNDAMENTAL GOAL OF THIS VISION IS TO ADVANCE
U.S. SCIENTIFIC, SECURITY, AND ECONOMIC INTEREST
THROUGH A ROBUST SPACE EXPLORATION PROGRAM**



Implement a sustained and affordable human and robotic program to explore the solar system and beyond

Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;

Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and

Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.



“Level 0” Exploration Requirements

Excerpted from NASA document SA-0001, 4 May 2004 Baseline

LEVEL 0 EXPLORATION REQUIREMENTS

- (1) NASA shall implement a safe, sustained and affordable robotic and human program to explore and extend human presence across the solar system and beyond.**
 - (1.1) NASA shall develop the innovative technologies, knowledge, capabilities, and infrastructure to support human and robotic exploration.**
 - (1.2) NASA shall conduct a series of robotic missions to the moon to prepare for and support future human exploration activities.**
 - (1.3) NASA shall conduct human lunar expeditions to further science, and to develop and test new exploration approaches, technologies, and systems, including the use of lunar and other space resources to support sustained human space exploration to Mars and other destinations.**
 - (1.4) NASA shall conduct robotic exploration of Mars to search for evidence of life, to understand the history of the solar system, and to prepare for future human exploration.**
 - (1.5) NASA shall conduct human expeditions to Mars to extend the search for life and to expand the frontiers of human exploration after successfully demonstrating human exploration missions to the moon.**



“Level 0” Exploration Requirements

Excerpted from NASA document SA-0001, 4 May 2004 Baseline

LEVEL 0 EXPLORATION REQUIREMENTS

- (2.0) NASA shall acquire an exploration transportation system to support delivery of crew and cargo from the surface of the Earth to exploration destinations and to return the crew safely.**
- (3.0) NASA shall complete assembly of the International Space Station, including the U.S. components that support U.S. space exploration goals and components provided by foreign partners, planned by the end of the decade.**
- (4.0) NASA shall pursue opportunities for **international participation** to support U.S. space exploration goals.**
- (5.0) NASA shall **pursue commercial opportunities** for providing transportation and other services supporting the International Space Station and exploration mission beyond low Earth orbit.**



Exploration “Level 0” Requirements

Excerpted from NASA document SA-0001, 4 May 2004 Baseline

LEVEL I EXPLORATION OBJECTIVES

- (1) NASA shall develop and demonstrate power generation, propulsion, life support, and other key capabilities required to support more distant, more capable, and/or longer duration human and robotic exploration of Mars and other destinations. (reference requirement – 1)
 - (1.1) Starting no later than **2008**, NASA shall initiate a series of **robotic missions to the Moon** to prepare for and support future human exploration activities. (reference requirement - 1.2)
 - (1.2) NASA shall conduct the **first extended human expedition to the lunar surface as early as 2015, but no later than 2020**, in preparation for human exploration of Mars and other destinations. (reference requirement - 1.3)
- (2) NASA shall **separate crew from cargo** for launches of exploration missions to the **maximum extent possible** (reference requirement - 2)
- (3) NASA shall conduct the **initial test flight for the crew exploration vehicle before the end of the decade** in order to provide an operational capability to support human exploration missions no later than 2014 (reference requirement – 3)



Exploration “Level 0” Requirements

Excerpted from NASA document SA-0001, 4 May 2004 Baseline

LEVEL I EXPLORATION OBJECTIVES

- (4) NASA shall retire the Space Shuttle as soon as assembly of the International Space Station is completed, planned for the end of this decade (reference requirement – 3)
- (5) NASA shall conduct International Space Station activities in a manner consistent with U.S. obligations contained in the agreements between the United States and other partners in the International Space Station. (reference requirement – 3)
- (6) NASA shall **acquire cargo transportation** as soon as practical and affordable to support missions **to and from the International Space Station.** (reference requirement – 3)
- (7) NASA shall **acquire crew transportation to and from the International Space Station, as required, after the Space Shuttle is retired from service.** (reference requirement – 3)



New National Space Transportation Policy

- **“The United States shall sustain a focused technology development program for next-generation space transportation capabilities to transform U.S. access to and use of space. In that regard, the Secretary of Defense and the Administrator of the National Aeronautics and Space Administration, in cooperation with industry as appropriate, shall:**
 - **“a) Within two years of the date of this policy, develop the requirements, concept of operations, technology roadmaps, and investment strategy for next generation space transportation capabilities with the objective of dramatically improving the reliability, responsiveness, and cost of Earth-to-orbit space transportation for deployment of spacecraft and other payloads in Earth orbit, exclusive of human space flight; and**
 - **“b) Pursue research and development of in-space transportation capabilities to enable responsive space transportation capabilities and the transformation of the Nation’s ability to navigate in space. These efforts shall include, but not be limited to: automated rendezvous and docking, and the ability to deploy, service, and retrieve payloads or spacecraft in low Earth orbit. The Administrator of the National Aeronautics and Space Administration, in cooperation with the Secretary of Energy and other departments as appropriate, shall pursue research and development of space nuclear power and advanced propulsion technologies to more quickly, affordably, and safely expand the reach of exploration into the solar system and beyond...”**



Roles and Responsibilities

- **Co-chairs**
 - **Oversee the work of the Strategic Roadmap Committee (SRC)**
 - **Help develop and concur on final committee product**
 - **Represent the committee and its products in public forums and within NASA**
 - **NASA Co-Chairs: represent views of their organization to the committee**
 - **External Co-Chair: represent views of their stakeholders or constituents to the committee**
- **Directorate Coordinator**
 - **Ensure consistent and clear communications with affected Directorates**
 - **Lead consolidation of legacy processes with requirements of the SRC goals and processes**
 - **Ensure smooth flow of Directorate planning efforts and products into the SRC activity**



Roles and Responsibilities

- **APIO Coordinator**
 - Play an active role in setting standards and policy
 - Convey APIO guidelines to the SRC
 - Help ensure inter-SRC coordination working with the APIO integration personnel
 - Work with APIO FACA coordinator to manage FACA notices, postings, and reporting requirements
 - Coordinate with the APIO logistics support contractor for meeting arrangements
- **Mission Directorate Coordinator, APIO Coordinator, and System Engineers**
 - Support co-chairs and committee members in carrying out their responsibilities
 - Perform up-front preparation for public meetings
 - Draft and revise material for review and approval of the committee
 - Synthesize results of meetings for review and approval the committee